CHAPTER 8

PRACTICE EXERCISES

SECTION I MULTIPLE CHOICE

1. A hydraulic lift is designed for a gain of 100, so that a 10 N force applied at the input piston will produce a force of 1,000 N at the output piston. If the radius of the input piston is 2 cm, the radius of the output piston is

(A) 200 cm (B) 0.02 cm (C) 400 cm (D) 20 cm (E) 0.05 cm

2. A cube of side L is made of a substance that is ¼ as dense as water. When placed in a calm water bath, the cube will

(A) float with $\frac{1}{2} L$ above the surface
(B) sink to the bottom
(C) float with $\frac{1}{4} L$ above the surface
(D) float with $\frac{1}{4} L$ below the surface
(E) float with $\sqrt[3]{\frac{1}{4}}$ below the surface

3. A cylindrical pipe has a radius of 12 cm in one region where the fluid speed is 0.2 m/s. In another region, the pipe is narrower with a radius of 4 cm. The fluid speed in this region is most nearly

(A) $9 \frac{\text{m}}{\text{s}}$ (B) $0.6 \frac{\text{m}}{\text{s}}$ (C) $1.8 \frac{\text{m}}{\text{s}}$ (D) $0.011 \frac{\text{m}}{\text{s}}$ (E) $0.067 \frac{\text{m}}{\text{s}}$

4. A water pump is attached to the left end of a horizontal pipe that consists of a rigid section and a flexible second section that can have its cross-sectional area adjusted. A pool needs to be filled with the output of the flexible section. Which of the following will increase the rate at which the pool will fill?
I. Increase pump pressure.
II. Decrease the cross-sectional area of the second section.
III. Increase the cross-sectional area of the second section.

(A) I only (B) II only (C) III only (D) I and II only (E) I and III only

5. An ideal fluid flows through a pipe that runs up an incline and gradually rises to a height H. The cross-sectional area of the pipe is uniform. Compared with the flow at the bottom of the incline, the flow at the top is

(A) moving slower at lower pressure
(B) moving slower at higher pressure
(C) moving at the same speed at lower pressure
(D) moving at the same speed at higher pressure
(E) moving faster at lower pressure

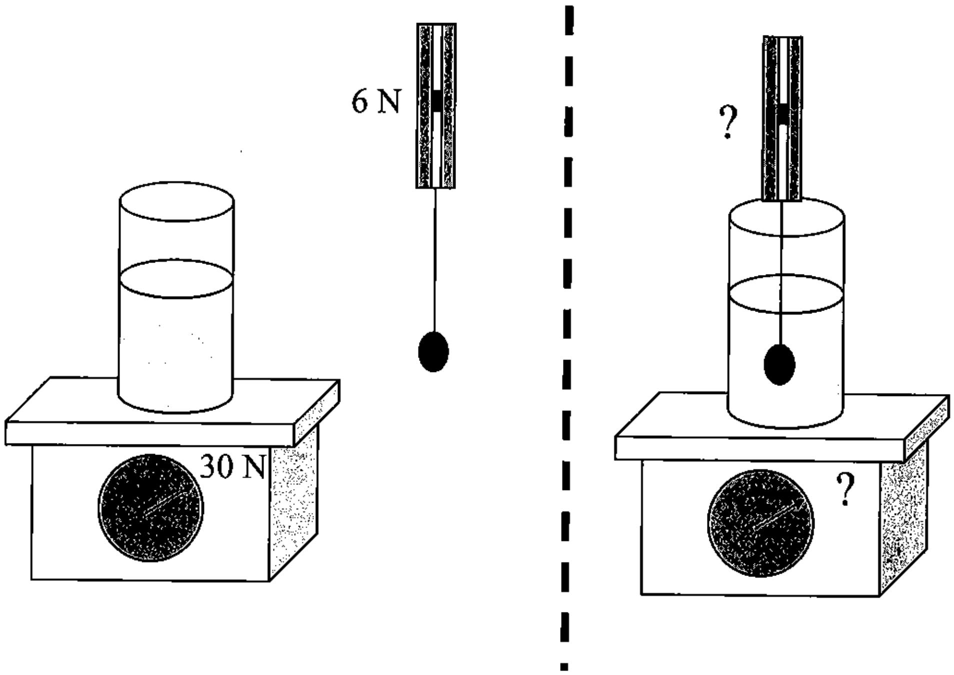

Figure 14

6. A beaker of water sits on an electronic scale with an initial reading of 30 N. A mass with 3 times the density of water hangs from a spring scale with an initial reading of 6 N. Still attached to the spring scale, the mass is completely immersed in the water. The readings on the two scales (in electronic, spring order) will be

(A) 30 N, 2 N (B) 32 N, 6 N (C) 36 N, 2 N (D) 32 N, 4 N (E) 36 N, 4 N

CHAPTER 8

PRACTICE EXERCISES

SECTION II FREE RESPONSE

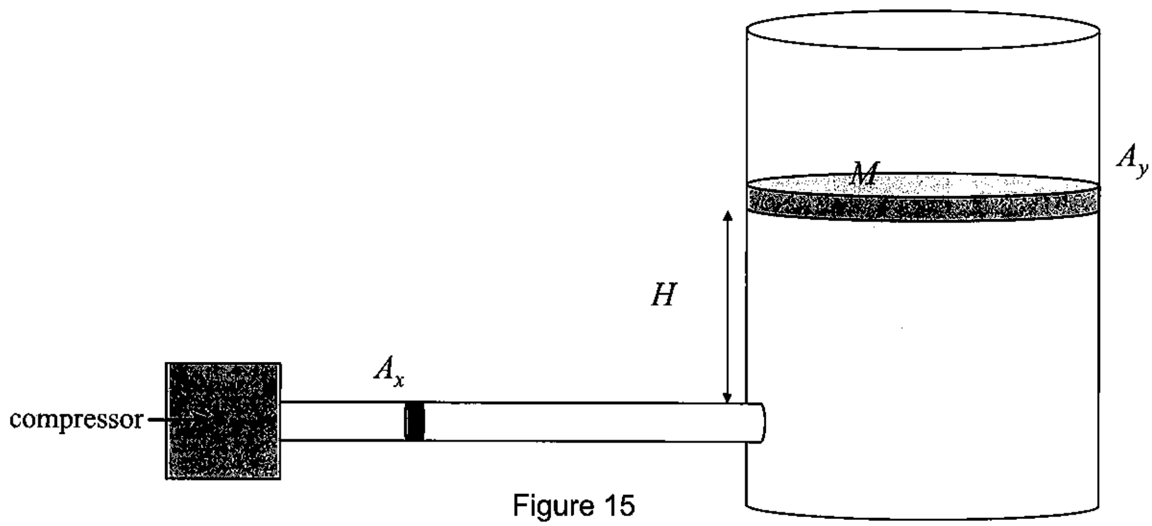

Figure 15

1. A piston of cross section A_x can move inside a long tube that's connected to a large cylindrical reservoir with cross section A_y of fluid that has a density ρ. Currently a piston of mass M is supported at the top of the cylinder at a height H above the long tube. Compressed air is pumped to the left of the small piston and maintains it in its current position.
   (a) Find the pressure of the compressed air.

   The piston needs to be raised an amount Δy.
   (b) How far must the small piston move?
   (c) How much must the air pressure be increased to lift the piston?

2. A vendor at a flea market for the rich and famous claims the crown he is selling is pure gold. On a precise spring scale, you weigh the crown and read a value of 25.14 N. Next, you immerse the crown in water while it's still hanging from the scale, this time getting a reading of 20.65 N. Since you know the ratio of gold density to water density is 19.32, what do you conclude about the vendor's claim?

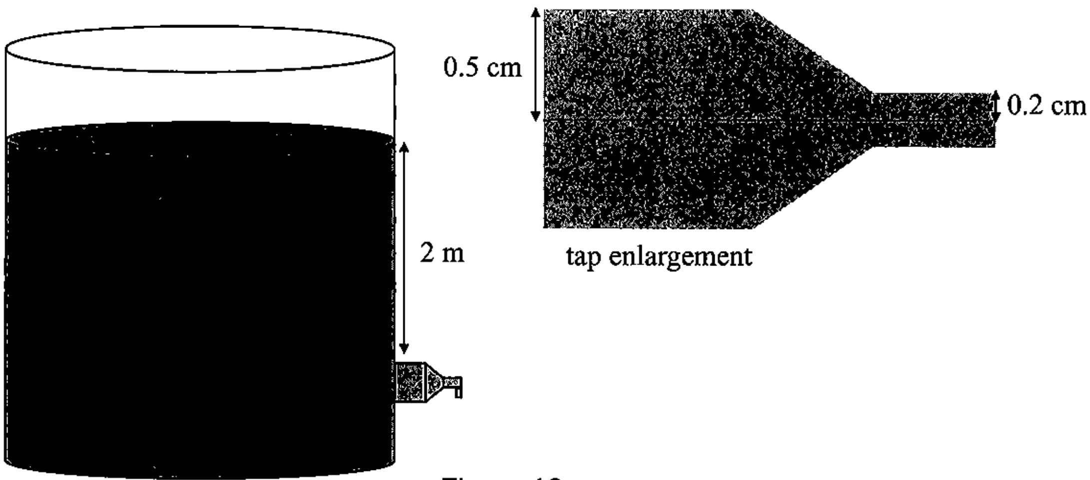

Figure 16

3. A large storage container in a commercial wine cellar is cylindrical in shape. To test the contents (density of 1,000 $\frac{\text{kg}}{\text{m}^3}$), you can insert a tapping mechanism near the base of the cylinder. This mechanism consists of a larger cylindrical pipe of radius 0.5 cm that narrows to 0.2 cm at the spigot. Currently, the tapping device is 2 m below the wine level in the container. Assume the space above the wine in the container is maintained at atmospheric pressure and that wine is an ideal fluid. You may also assume that loss of wine through the spigot does not appreciably change the volume of wine in the container.
   (a) Find the time it will take to fill a 1 L flask at the spigot.
   (b) Determine the speed of the fluid as it enters the tapping device.
   (c) Find the difference between atmospheric pressure and the fluid pressure just inside the tapping device.

Answers and Explanations

Multiple Choice

1. The answer is D. $F_{out} = F_{in}\frac{A_{out}}{A_{in}} = F_{in}\frac{\pi r^2_{out}}{\pi r^2_{in}}$, so $1{,}000 = 10\frac{r^2_{out}}{2^2} \Rightarrow r_{out} = 20$ cm

2. The answer is D. The object will float because it is less dense than water, and it will displace an amount of water just equal to its weight. Since water is 4 times as dense, it will displace only one-quarter of its volume, so that one-quarter of the "height" will lie below the surface.

3. The answer is C. The continuity equation is

$$A_1v_1 = A_2v_2 \Rightarrow v_2 = v_1\frac{A_1}{A_2} = (0.2)\frac{\pi(12)^2}{\pi(4)^2} = 1.8\frac{\text{m}}{\text{s}}$$

4. The answer is A. Since the pressure at the end of the line is always one atmosphere, Bernoulli's equation tells you that increasing the pressure at the beginning will result in an increase in the fluid speed at the end of the line for any cross section. Changing the cross-sectional area will not affect the amount of water that gets into the pool; the continuity equation states that the same amount will flow.

5. The answer is C. Since the area didn't change, the continuity equation implies that the fluid speed remains the same. Bernoulli's equation then tells you that the pressure at height H must be less.

$$\frac{1}{2}\rho v_{bot}{}^2 + p_{bot} = \frac{1}{2}\rho v_{top}{}^2 + \rho gH + p_{top} \qquad v_{bot} = v_{top}$$

$$p_{top} = p_{bot} - \rho gH$$

6. The answer is D. Since the density is 3 times as great as water, the object will experience a buoyant force of one-third its weight, or 2 N. The spring scale will then read 6 − 2 = 4 N. The reaction to the buoyant force acts on the water and eventually the electronic scale, producing an extra downward force of 2 N. The scale then reads 32 N.

FREE RESPONSE

1. (a) Without the upper piston, the pressure at the lower piston is just the fluid pressure at depth h. Adding the piston weight creates an extra pressure of $\frac{M_g}{A_y}$, which will be transmitted undiminished to all points within the fluid. The total pressure the compressed air must supply is

$$p_{air} = \rho g h + \frac{M_g}{A_y}$$

(b) The fluid volume increase in the large cylinder must equal the fluid volume change in the tube.

$$A_y \Delta y = A_x \Delta x \Rightarrow \Delta x = \Delta y \frac{A_y}{A_x}$$

(c) The increase in pressure is needed to support the extra fluid in Δy. The old pressure could already support the piston and the fluid to height H, so

$$\Delta p = \rho g \Delta y$$

2. The difference in the two scale readings is the buoyant force (the buoyancy of air isn't taken into account). Since this is the weight of the displaced water, you have

$$\Delta W = 25.14 - 20.65 = 4.49 = \rho_{\text{water}} g V_{\text{crown}} \Rightarrow V_{\text{crown}} \Rightarrow V_{\text{crown}} = \frac{4.49}{\rho_{\text{water}} g}$$

Then use the first reading to calculate the density.

$$\rho_{\text{crown}} = \frac{M_{\text{crown}}}{V_{\text{crown}}} = \frac{W_{\text{crown}}}{g V_{\text{crown}}} = \frac{25.14}{\left(\frac{4.49}{\rho_{\text{water}}}\right)} \Rightarrow \frac{\rho_{\text{crown}}}{\rho_{\text{water}}} = 5.60$$

The crown is much less dense than pure gold, and the vendor is mistaken.

3. (a) Apply Bernoulli's principle, comparing the spigot output, where the pressure is just atmospheric pressure, to the fluid at the top of the container, where the fluid is essentially at rest and where the pressure is also one atmosphere.

$$\frac{1}{2}\rho v_1^2 + \rho g h_1 + p_1 = \frac{1}{2}\rho v_2^2 + \rho g h_2 + p_2^2$$

$$0 + \rho g h + p_{\text{atm}} = \frac{1}{2}\rho v^2_{\text{out}} + p_{\text{atm}}$$

$$v_{\text{out}} = \sqrt{2gh} = 6.32\tfrac{\text{m}}{\text{s}} = 632\tfrac{\text{cm}}{\text{s}}$$

Since the area of the spigot opening is $\pi(0.2)^2$, in a time T, the output volume of the spigot will be

$$V_{\text{out}} = \pi(0.2)^2(632)T$$

Since you need 1 L = 1,000 cm^3, you have

$$1{,}000 = 79.4T \Rightarrow T = 12.6\text{s}$$

(b) You can apply the continuity equation comparing the spigot output with the input of the tapping device.

$$A_{in}v_{in} = A_{spig}v_{spig} \Rightarrow v_{in} = v_{spig}\frac{A_{spig}}{A_{in}} = \frac{6.32\pi(0.2)^2}{\pi(0.5)^2} = 1.01\frac{\text{m}}{\text{s}}$$

(c) Use Bernoulli's equation, comparing the top of the fluid with the beginning of the tap.

$$\frac{1}{2}\rho v_1{}^2 + \rho g h_1 + p_1 = \frac{1}{2}\rho v_2{}^2 + \rho g h_2 + p_2$$

$$0 + \rho g h + p_{atm} = \frac{1}{2}\rho v_{in}{}^2 + p_{in}$$

$$p_{in} - p_{atm} = (1{,}000)(10)(2) - \frac{1}{2}(1{,}000)(1.01)^2$$

$$\Delta p = 1.95 \times 10^4 \text{Pa}$$